

PROCEEDINGS

AMERICAN SOCIETY OF CIVIL ENGINEERS

MARCH, 1954



FILL UTILIZATION FOR BUILDING FOUNDATIONS

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Presented at
Atlanta Convention
February 15-19, 1954

SOIL MECHANICS AND FOUNDATIONS DIVISION

{Discussion open until July 1, 1954}

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Printed in the United States of America*

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE \$0.50 PER COPY

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

FILL UTILIZATION FOR BUILDING FOUNDATIONS

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INTRODUCTION

The purpose of this paper is to present as completely as possible the current approach to foundation designs, utilizing fill. Many of the foundation types and methods which will be covered are nationally used, but we shall deal with their use as associated with fill materials encountered or available in the Southeast. This means, that we will stress particularly those soils of the Piedmont and Coastal Plain areas.

In the process of developing our subject it will be necessary to both review and restate currently applied knowledge. In like manner, the paper if to be complete, entails that the following considerations be discussed.

1. Fill defined, its possible occurrence, and the preliminary engineering approach.
2. The selection and placement of soils for new fill.
3. The engineering aspects of foundations involving fill.
4. The probable results and evaluation of the completed project.

Fill - Definition, Occurrence, and Engineering Approach Defined

What the writer considers to be the most accurate and concise definition of fill has been given by Taylor:²

"Fill is a term that applies to all man-made deposits ranging from sand and gravel fills or rock piles to dumps. Fills may contain every imaginable material."

With this definition alone the engineer is prepared to expect anything. The fills that we have encountered usually disclose one of the following three natures: garbage and litter dumps dating from the early growth of the city or area, fairly clean soil interspersed with domestic waste in a loose and erratic condition, or lastly, a clean soil fill with little vegetation either deposited loosely or in a firm condition. The latter are rare and are the result of a definite intent to utilize the fill later for building sites. Even then, however, we find that every fill requires special attention before a foundation is determined. If these conditions do exist, why then is there any interest in fill or make-up ground as a building site?

Occurrence

In the past growth of many of our Southeastern cities, with the exception of a few coastal municipalities, there has been little need for consideration of

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1. Soils Engineer, Law-Barrow-Agee Laboratories, Inc., Atlanta, Ga.
 2. "Fundamentals of Soil Mechanics," by Donald W. Taylor. John Wiley & Sons, Inc., New York, New York, 1948, p. 53.

apparently abandoned and semi-worthless areas for building purposes. These areas are the ones which include the fills spoken of above. The picture, however, has changed. There is a sudden rush toward an urban development. In some cases even a decentralization into previously ignored quasi-rural areas has taken place. The demands for building sites to provide shopping centers, freight terminals, and warehouse facilities, to name a few, have taken their toll of desirable sites. What has been left are those areas with the least desirable soil conditions. It has now become the wish of realtors and investors to reclaim even these, and present them to clients as possible building sites. This has thrown the burden on the engineer to develop foundation on such fill material. Little need be said of the indecisions which will be his in the months that follow. But since it is our problem, there are certain steps that should be taken to provide the engineer with a working knowledge of his foundation material.

Engineering Approach

We have learned that there are two primary requisites necessary before a foundation can be considered satisfactory.

- a. Safe against bearing failure.
- b. Safe from excessive settlement.

In the determination of both of these the prospective owner has the responsibility of providing the engineer with adequate foundation information. This should be in the form of a site exploration with subsequent laboratory tests if required. It should be stressed that a surface appraisal is not enough, rather a sub-surface exploration should be made. With the information that present soil investigations can provide, the engineer has gone a long way in the solution of his problems. With these data he can begin to determine the need for special structural and foundation details. He may even realize that the site cannot be developed and complete abandonment is the more sensible step.

It is not felt that a detailed coverage of the extent of a soil investigation need be included in this paper but the following items are the minimum that should be obtained:

1. Depth of fill.
2. Nature of the fill material, including penetration resistances when possible.
3. Investigation of underlying virgin soil.
4. Undisturbed samples for laboratory tests in fill and/or virgin soil.

Although the procurement of these items may appear to entail a considerable investigation, it has been found more costly to design a foundation on less information.

We have been dealing heretofore with existing fills. There are occasions, however, when much of the above is not applicable; this being when the fill is placed under the direction of the responsible engineer.

Soil Selection and Placement for New Fills

Soil Selection

In the selection of any fill material some limitation is imposed by the availability of satisfactory material. In the Southeast we are supplied with a

variable group of soils depending on the locale. Atlanta, resting on the lower plains of the Piedmont Range, has the choice of residual soils resulting from the weathering or decomposition of the base schist or gneiss rock. These may be encountered as clays, micaceous silts or partially decomposed rock ranging from fine sand to gravel in size. Further South, in the Coastal Plain area, we have sand overlying a stiff mottled clay. Still further south and along the east coast are the marsh silts, alluvial sands, and soft plastic clays. In addition to these natural deposits, there is the availability of domestic and industrial waste materials, a few of these being satisfactory as fill material.

Each material cited has its advantage or disadvantage dependent on its proposed use. It must under normal operation as a fill material meet these main considerations: compact easily, be fairly incompressible, and be insensitive to excess moisture.³ Few of the soils in the Piedmont area fulfill these three requirements completely. In rather shallow fills, however, the clays and micaceous silts displaying some cohesion are satisfactory. They normally can receive their loads immediately when properly compacted. It does prove advantageous on occasions to include with these cohesive soils materials possessing some internal friction. This materially adds to the stability of the fill and gives some help to drainage requirements.

The coarser granular materials, rock and gravel, are ideal when well graded for deep fills and should be compacted to their maximum density ranging between 125 and 140 lbs per cu ft. It has been the practice, to date, to use these coarser materials in dams and larger fill areas only.

Hydraulic sand fills have been tried on occasions in isolated areas where conditions were conducive to this method. It has never gained too much popularity in the Southeast, however, even when a ready supply of sand was available. (This applies to building foundations only.)

The use of domestic and industrial waste even when selection is possible has proven less desirable than natural soils. There have been instances when such industrial waste has been used as the lesser of two evils. A case in point would be the New York World Fair Site which received much attention at the time. There it was the use of an industrial ash or cinder waste rather than a soft plastic silt. A few of the materials available here in the South are foundry waste, slag, ashes, building materials, and broken rock. Incidentally many of these same materials are exposed in existent fills within this area.

Returning again to the clays and micaceous sandy silts of this immediate region, we shall explore their use as a satisfactory fill material. The plastic clays should not be employed in a fill over 15 ft in height, and then should be reserved for single storied office buildings or schools. Their usual maximum dry densities lie between 95 and 112 lbs per cu ft, with reduction when mica is present. The micaceous sandy silts are less desirable than the clays although they display two advantages to the compaction contractor; ease of compaction to a 95% value, and abundance of supply. The fills composed of such silty soils should seldom exceed 10 ft and then every effort should be made to obtain dry densities of from 87 to 102 lbs per cu ft. Both the clays and silts are sensitive to moisture changes. This is apparent in the shape of the compaction curve which displays a sharp rise at the optimum moisture point. Drainage is poor and some swelling can occur as the result. When compacted at above optimum moisture some settlement of the fill can be expected.

Further can be said of the actions of the fill when the type of foundation is

3. "The Engineering Properties of Georgia Soils," by George F. Sowers, The Geological Survey, Bulletin No. 60, 1953, p. 173.

proposed. The next item to be considered after selection has been made is the placement of the fill soils. It is also readily apparent to the engineer that selection and placement are pointless unless controls over both are observed.

Soil Placement

Many good college texts on soil mechanics include a section on standard tests for the determination of the optimum moisture and maximum density. It still presents a problem, however, when the fill contractor is left the responsibility of obtaining and evaluating these tests. In many instances it has been found that the engineer has specified certain fill control tests only to find that the contractor was unable to interpret his request. This results in a faulty fill, if not one completely unsuitable, which may require the delay and expense of replacement.

The main items for our consideration at this stage of operations are these:

1. That representative samples of the materials to be used in the fill are made available for standard or specified laboratory compaction tests.
2. That the laboratory compaction tests specified approximate the same compaction effort as will be realized from the field equipment.
3. And that a sufficient number of field density checks are made initially and throughout the filling operations to ensure that explicit desires are being obtained. This latter item may require that corrective laboratory and field work be done.

In addition, one of the above items without the other puts undue responsibility on either the contractor, engineer, or laboratory.

Little need be said to most practicing engineers about the equipment available for compacting operations. Each group of soils has a type of equipment best suited for its proper compaction. In this area, the sheepfoot roller and pneumatic tired buggies are most frequently used with very favorable results. Further south one can best use weighted multiple tired buggies, vibrators, and tractor treads.

Assume that we now have one of two types of fill, either an investigated old fill or one compacted for the particular job. Our next step is to consider the best foundation possible on such fills.

The Engineering Aspects of Foundations Involving Fill

Perhaps the most often encountered fill is one used to provide a level grade for the construction of a slab on grade. These fills are usually several feet deep and are composed of the soils at the site. Since the building may rest on both fill and leveled virgin soil the possibility of differential settlement must be considered. The slab foundation must include additional reinforcing to protect against possible damage from this effect. No condition has come to the attention of the writer in this respect that has necessitated a rigid type slab or mat.

A variation of the slab on ground has utilized a rigid or semi-rigid box construction acting as a floating foundation on very soft organic or garbage fill. Also in current use is the rigid grade beam carrying the curtain wall and roof with the slab taking the floor loads. This latter technique has been used a great deal in the construction of single story school buildings where loads are exceptionally light. The use of such beams allows the bridging of

soft pockets that may be inherent in the fill. It also spreads the floor loads over such a large area that the likelihood of settlement is remote. Even if settlement is realized the separation of the slab and rigid beam doesn't cause undue cracking in either.

As we view the buildings carrying heavier loads the slab is still retained on the fill but the column and wall loads are taken to virgin material. Most often this is done by placing spread footings on the virgin soil and coming up to floor grade by piers. These are then enclosed in compacted fill, a rigid grade beam is added and the floor slab poured. This method has proven very satisfactory for new fills and some existing old fills when the virgin material was within 25 ft and the fill was capable of supporting the floor loads. A large warehouse was recently constructed in this manner and proved very economical. The filling was controlled and although a micaceous sandy silt was used for a 12 ft height no appreciable settlement has been observed. In the design of such foundation we have often found that the spread footings could have easily been placed on the fill. This is particularly true when the virgin material is less dense than the placed fill. The fill usually acts as a blanket over the softer soils thereby reducing likely settlements.

One case which displays the unfavorable results of this construction may be of interest. The fill to be utilized was existent and was composed of debris, soil, and miscellaneous auto body parts. The plan was to clear a trench down the column lines to virgin soil varying in depth over the site from 5 to 35 ft. Spread footings were to be poured at this level and concrete piers carried up to the grade whereon the floor slab would be placed. The trench was opened by a bulldozer and the virgin material proved to be a very loose sandy organic silt. The footings were poured at this level after pin-piles were driven with a jack hammer some 4 ft to what they considered refusal. A concrete pier was then constructed to the floor grade, and backfilled with the still available excavated material. As an added safety factor the floor slab was supported at about 10 ft intervals on wood piles driven into or through the fill at its deepest end. We were called in as soils engineers at this point when six inches of settlement had supposedly been observed on the column piers. We could do little more than enumerate what probably had happened and assume that more settlement would take place. Much of what did occur could have been avoided had the proper steps been taken before the foundation was begun.

Another means of foundation design utilizing fill employs the use of a drilled pier. This technique has been very satisfactory in fills where the water table is not critical or the fill too loose to maintain the sides for a 30 minute period. These drilled piers are similar to the Texas Caisson and the belled bottom can be used to advantage in reducing the load pressures. One case with which the writer is familiar used numerous such piers drilled through cinders, foundry waste, and soft silty soil. They had no trouble penetrating 40 ft or more in such material. The resulting piers were required to resist lateral movements as well as vertical loads. One of the versatile traits of this operation appears to be in the size of borings obtainable. On another job a 12 inch augered pier was made in contrast to the 36 inch boring made for the piers above. This small pier was used as a support feature in the foundations for six homes to be located on a soft wedge of fill. Their lengths were determined by the depth to a stiffer clay layer at the base of the fill. These drilled piers were favored over a mat foundation both on a monetary and engineering basis. The engineering features of the fill required that safety against a sliding failure be incorporated in the foundation design. This

was done by "keying in" the foundations with these piers taking them through the soft micaceous silt. It is also of interest to note the complete lack of consolidation of the silt material even after 20 years had elapsed since the clean soil was dumped at the site. The upper crust of clay had desiccated into a stiff consistency and the lower clay had consolidated into a stiff material but the intermediate silt was as loose as originally deposited.

Other foundation types which can be used to advantage when the soil is predominately sand are vibrofloatation and mixed-in-place piles. Although the former is not in itself a true supporting unit, it provides a means of preparing an otherwise loose sandy fill for foundation service. Usually a mat or slab foundation with spread footings are then used as the true foundation. The mixed-in-place piles are a relatively new phase of Intrusion Prepacked activities. Their construction involves the introduction of a grout into the soil as a patented auger is rotated and withdrawn from the auger hole. Though still in the development stage, these piles have proven very satisfactory in sand; and research is continuing to extend their use into other materials. The method shows promise of fulfilling many foundation requirements of the Southeast.

The Probable Results and Evaluation of the Completed Project

The likely results of the various types of foundations placed on fill could involve voluminous discussion and still be nothing more than pure conjecture. There are some general observations, however, that have been made which may prove of interest as to the possible action of completed fills before and after loading.

The most pronounced subsidence comes from the consolidation of the soil within the fill from the weight of the fill itself. There have been various values cited for the expected amounts and all may be conservative or critical depending on the precise make up of the fill. A rubbish fill is particularly noteworthy in this respect. They have been known to settle some 15% of their original height and still prove unsatisfactory for any but the lightest loads. Any foundation that is designed to go on such fills, even after an extended period (say 30 years), should have bearing pressures below 1000 lbs per sq ft.

Cohesive materials, such as clay and some silts, are next in the magnitude of subsidence that is possible. Observations made on such material, dumped loosely, indicate that as much as 10% of the original height can be realized as settlement, this amount being measured after the fill had been in place 10 to 20 years. Even though the settlement could be excessive the penetration resistances of the soil ranged between 5 and 7 blows per ft on a standard split spoon.

A poorly compacted sand has given settlement up to 5% of the fill depth, but some vibratory loads were present. If the loads are static this value could easily remain below 3% of the fill height, even on uncompacted fills. An uncompacted, dumped rock and gravel fill usually experiences as little as 2% subsidence in its height.

A compacted clay fill composed of a good selected material and rolled to a 95% compaction should show negligible settlement under most expected loads. This is true for almost a five year period, after that some slight settlement may be realized. In a well compacted micaceous sandy silt fill some settlement is usually experienced but often during the early stages of construction. This one fact has prevented numerous unsightly cracks in masonry walls that are normally added last.

A compacted fill of silty sand with a dry density of 98 lbs per cu ft has shown a settlement of 3% of its initial height. This doesn't appear to be the usual case, however. More often, in clayey or silty sand fills, the settlement is not an important factor at all.

The precise relationship between a virgin soil and a fill with a slightly higher density than the virgin soil has not been derived, but every indication shows that the virgin soil is still the more desirable of the two. It is hard for man to disturb and recompact the soil as well as nature. There have been many instances when it was believed that the fill was more desirable than the virgin soil, and as far as bearing capacity was concerned this was probably true. Settlement still seems to be the main disadvantage to deep fills in this area, however.

Another point which has received some attention is the blanketing effect of fill. Does it actually span across softer areas in the underlying virgin soil? Most of the observations that have been made by the writer show no evidence of isolated settlement pockets in the fill after several years of operation.

Another point of interest is the continued development of a dish shaped depression even in the fill when placed over a soft plastic virgin material. This same dish shaped configuration is reflected in the column spread footings placed on the underlying virgin soil. This is a good argument against taking such footings to virgin soil when perhaps less settlement would be experienced if they were placed on top of the compacted fill.

CONCLUSION

There are five items which have been stressed throughout this paper, and it is felt they should be reiterated in conclusion.

1. Fills are a special engineering problem no matter what the fill status, and sufficient information for the solution of the problem is required.
2. The placement of new fill requires that a complete and integrated program must be adapted. This implies that close coordination between engineer, contractor, and laboratory should be requested.
3. The special features of design on any fill require that only the basic foundation types be investigated and adapted to fit the need. This does not mean in a hybrid sense but only in a good engineering fashion.
4. Probable results, although speculative, can be estimated from past experience and continued observations.
5. Many of the techniques associated with soil mechanics as to undisturbed samples cannot be directly correlated to fill samples. However, with continued research much additional information can be obtained that will put fill operations and evaluations on a more orderly and scientific basis.

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VOLUME 79 (1953)

MARCH: 176(SA), 177(EM), 178(HY), 179(EM), 180(HY), D-123(HY), D-126(ST), D-128(ST).

APRIL: 181(WW), 182(ST), 184(HY), 185(EM), 186(HY), 187(ST), 188(HY), D-135(HY), D-136(ST).

MAY: 189(HY), 190(HY), 191(CP) & (AT), 192(SM), 193(HY), D-129(PO), D-138(CP), D-145(ST).

JUNE: 194(CP) & (AT), 195(SM), 196(CP) & (AT), 197(HY), 198(ST), 199(EM), D-134(HY), D-141(HY).

JULY: ^a 200(SM)^b, 201(ST)^b, 202(EM)^b, 203(SM)^b, 204(AT)^b, 205(EM)^b, 206(ST)^b, 207(SA)^b, 208(SA)^b, 209(ST)^b, 210(SU)^b, 211(EM)^b, 212(SU)^b, 213(IR)^b, 214(HW)^b, 215(SM)^b, 216(ST)^b, 217(ST)^b, 218(ST)^b, 219(ST)^b, 220(SM)^b, 221(HW)^b, 222(SM)^b, 223(EM)^b, 224(EM)^b, 225(EM)^b, 226(CO)^b, 227(SM)^b, 228(SM)^b, 229(IR)^b.

AUGUST: 230(HY), 231(SA), 232(SA), 233(AT), 234(HW), 235(HW), 237(AT), 238(WW), 239(SA), 240(IR), 241(AT), 242(IR), 243(ST), 244(ST), 245(ST), 246(ST), 247(SA), 248(SA), 249(ST), 250(EM)^c, 251(ST), 252(SA), 253(AT), 254(HY), 255(AT), 256(ST), 257(SA), 258(EM), 259(WW).

SEPTEMBER: 260(AT), 261(EM), 262(SM), 263(ST), 264(WW), 265(ST), 266(ST), 267(SA), 268(CO), 269(CO), 270(CO), 271(SU), 272(SA), 273(PO), 274(HY), 275(WW), 276(HW), 277(SU), 278(SU), 279(SA), 280(IR), 281(EM), 282(SU), 283(SA), 284(SU), 285(CP), 286(EM), 287(EM), 288(SA), 289(CO).

OCTOBER: ^d 290(all Divs), 291(ST)^c, 292(EM)^c, 293(ST)^c, 294(PO)^c, 295(HY)^c, 296(EM)^c, 297(HY)^c, 298(ST)^c, 299(EM)^c, 300(EM)^c, 301(SA)^c, 302(SA)^c, 303(SA)^c, 304(CO)^c, 305(SU)^c, 306(ST)^c, 307(SA)^c, 308(PO)^c, 309(SA)^c, 310(SA)^c, 311(SM)^c, 312(SA)^c, 313(ST)^c, 314(SA)^c, 315(SM)^c, 316(AT), 317(AT), 318(WW), 319(IR), 320(HW).

NOVEMBER: 321(ST), 322(ST), 323(SM), 324(SM), 325(SM), 326(SM), 327(SM), 328(SM), 329(HW), 330(EM)^c, 331(EM)^c, 332(EM)^c, 333(EM)^e, 334(EM), 335(SA), 336(SA), 337(SA), 338(SA), 339(SA), 340(SA), 341(SA), 342(CO), 343(ST), 344(ST), 345(ST), 346(IR), 347(IR), 348(CO), 349(SM), 350(HW), 351(HW), 352(SA), 353(SU), 354(HY), 355(PO), 356(CO), 357(HW), 358(HY).

DECEMBER: 359(AT), 360(SM), 361(HY), 362(HY), 363(SM), 364(HY), 365(HY), 366(HY), 367(SU)^e, 368(WW)^e, 369(IR), 370(AT)^e, 371(SM)^e, 372(CO)^e, 373(ST)^e, 374(EM)^e, 375(EM), 376(EM), 377(SA)^e, 378(PO)^e.

VOLUME 80 (1954)

JANUARY: 379(SM)^e, 380(HY), 381(HY), 382(HY), 383(HY), 384(HY)^e, 385(SM), 386(SM), 387(EM), 388(SA), 389(SU)^e, 390(HY), 391(IR)^e, 392(SA), 393(SU), 394(AT), 395(SA)^e, 396(EM)^e, 397(ST)^e.

FEBRUARY: 398(IR)^f, 399(SA)^f, 400(CO)^f, 401(SM)^f, 402(AT)^f, 403(AT)^f, 404(IR)^f, 405(PO)^f, 406(AT)^f, 407(SU)^f, 408(SU)^f, 409(WW)^f, 410(AT)^f, 411(SA)^f, 412(PO)^f, 413(HY)^f.

MARCH: 414(WW)^f, 415(SU)^f, 416(SM)^f, 417(SM)^f, 418(AT)^f, 419(SA)^f, 420(SA)^f, 421(AT)^f, 422(SA)^f, 423(CP)^f, 424(AT)^f, 425(SM)^f, 426(IR)^f, 427(WW)^f.

a. Beginning with "Proceedings-Separate No. 200," published in July, 1953, the papers were printed by the photo-offset method.
b. Presented at the Miami Beach (Fla.) Convention of the Society in June, 1953.

c. Presented at the New York (N.Y.) Convention of the Society in October, 1953.

d. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.

e. Discussion of several papers, grouped by divisions.

f. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.

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